EXPERIMENT OPERATIONS OVERVIEW

J. C. DUNLOP

BROOKHAVEN NATIONAL LABORATORY
a passion for discovery
U.S. DEPARTMENT OF ENERGY | Office of Science

Overview

Four main activities in experimental operations

Until FY2016: Reap physics of RHIC II upgrades

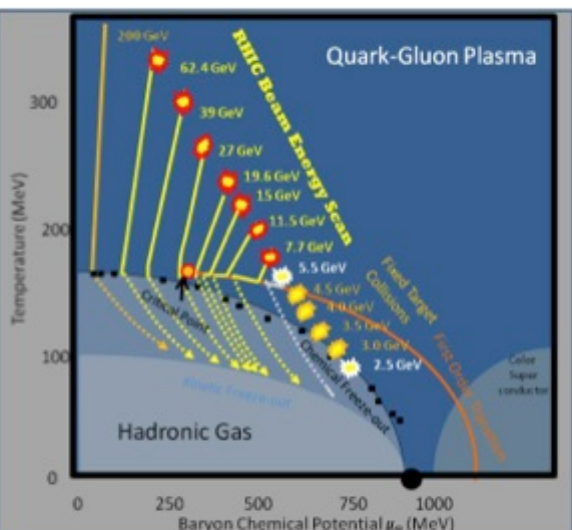
After this, three-fold support for the community

STAR and RHIC: low-energy electron cooling for Beam Energy Scan Phase 2

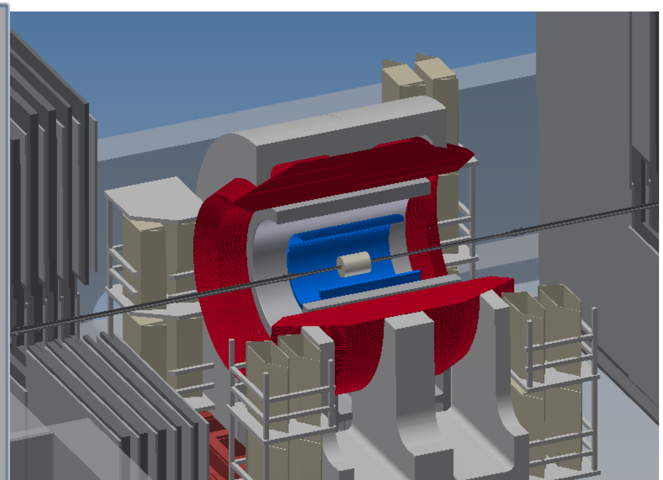
PHENIX transition to sPHENIX by FY21 run

Grow community for EIC: e.g. Generic EIC detector R&D

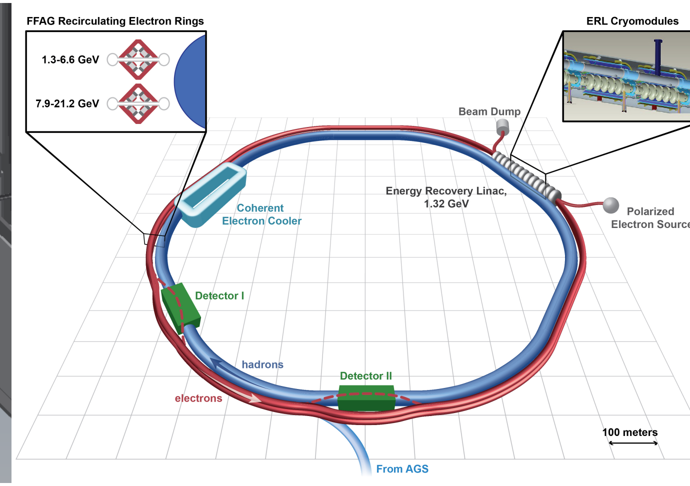
FY18-19



FY21-22

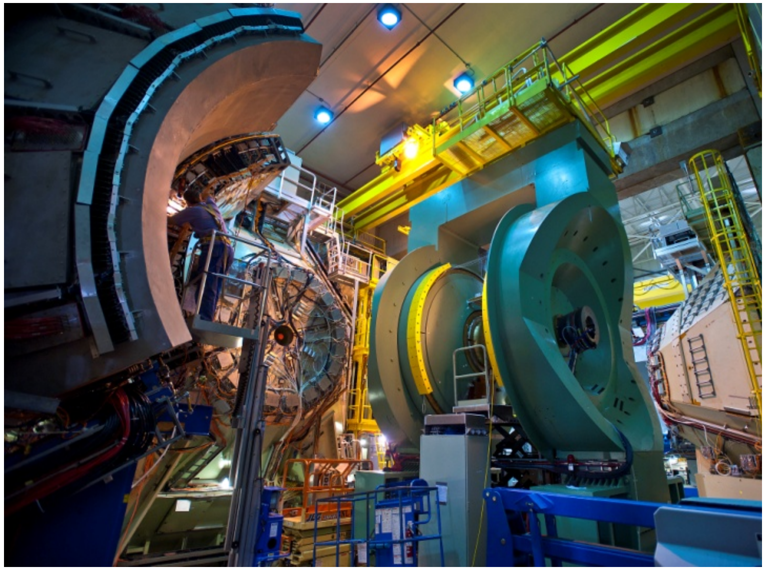


FY25+



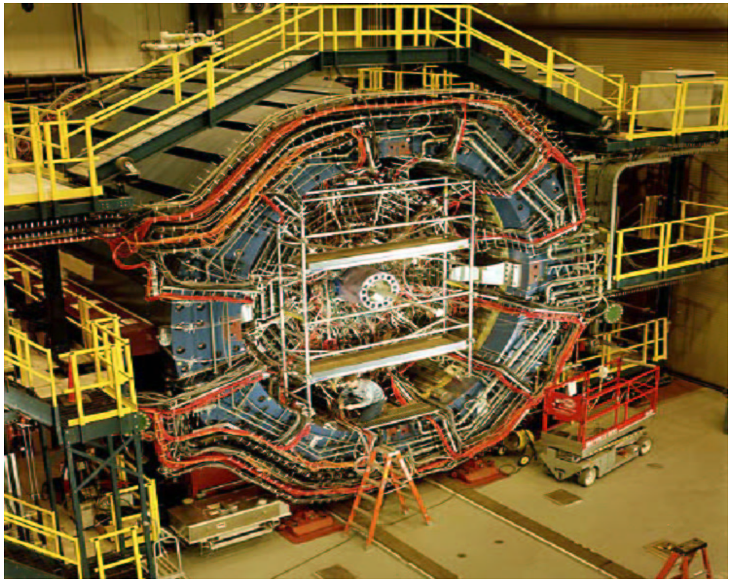
Two Large Multi-purpose Experiments

PHENIX



4 Large Spectrometer Arms
(2 Central(e,γ,h),2 Fwd (μ))
18 Subsystems
550 Collaborators
75 Institutions
15 Countries

STAR



2 π Detector
Large TPC and Solenoid
>10 Subsystems
580 Collaborators
59 Institutions
12 Countries

Two Large Multi-purpose Experiments

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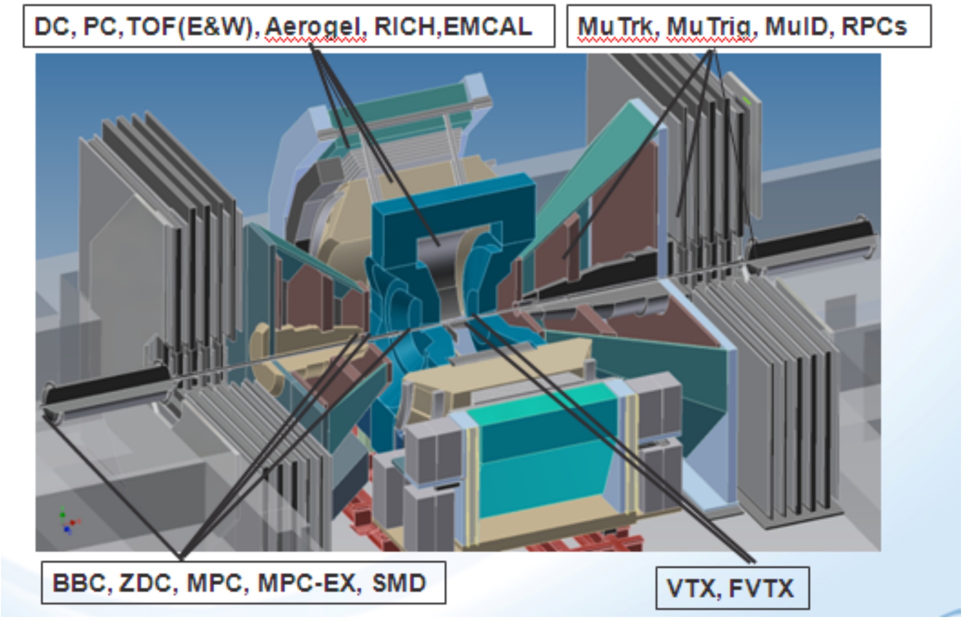

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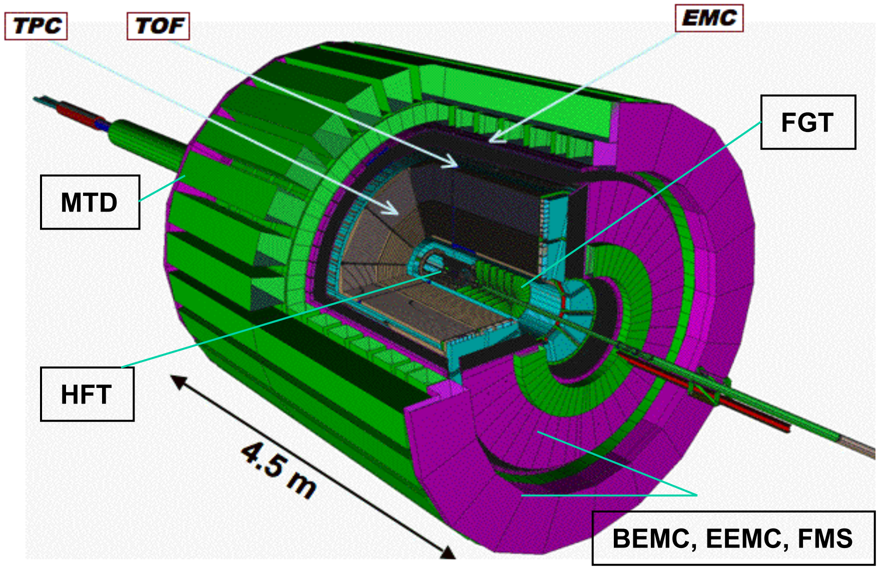


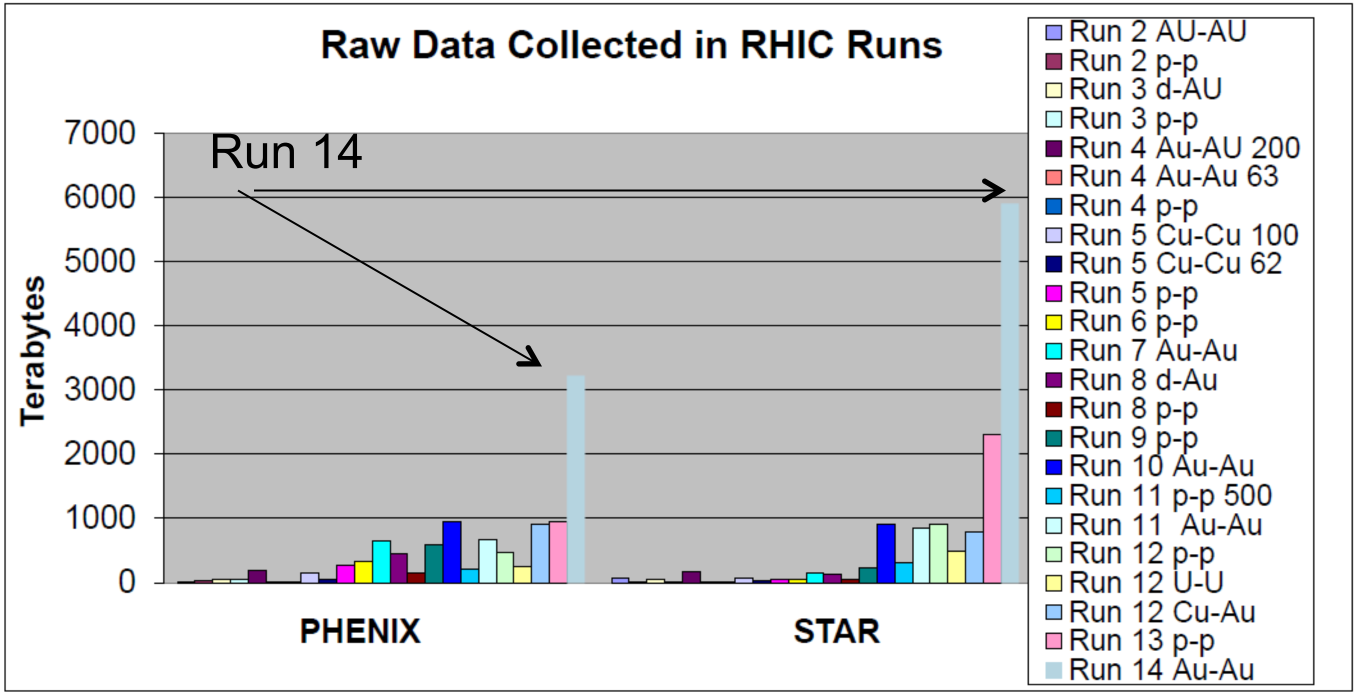
2 π Detector
Large TPC and Solenoid
EM Calorimetry over broad range
>10 Subsystems
580 Collaborators
59 Institutions
12 Countries

RHIC Computing Facility...

A shared facility with ATLAS Tier-1 Center:
Comparable staffs for both NP and HEP

Provides >90% (PHENIX), >85% (STAR) CPU resources

Michael Ernst, Director

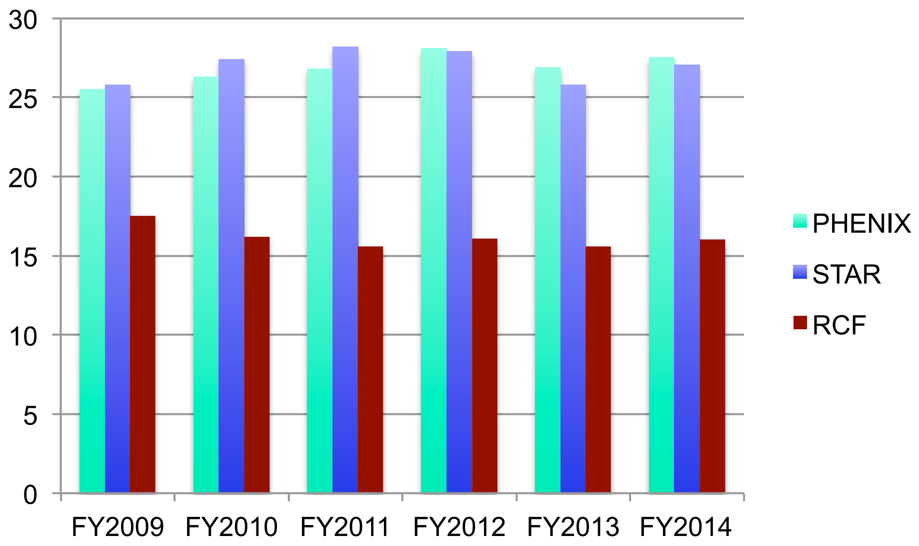


Online recording of raw data
Primary facility for data reconstruction and analysis
Long-term archiving and serving of all data

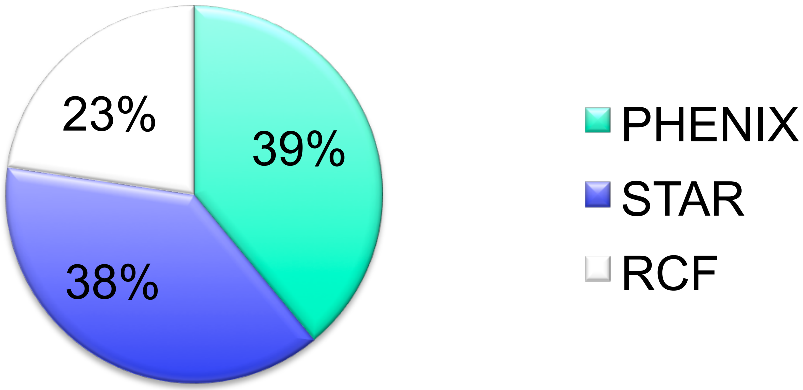
Operations and Capital Equipment budget: refurbishment and extension of capabilities
Optimization to match requirements of experiments

Operations Staffing Levels

Operations FTE's



FY2014



- Operations staffing levels approximately constant over time

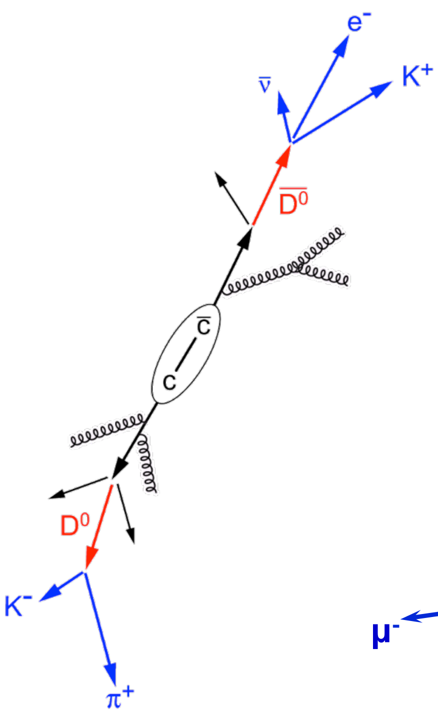
  PHENIX needs increased in FY12 with VTX

  Funding for additional HFT responsibilities in STAR, from HFT Contingency Spending Plan, are at other institutions, and will not be reflected here

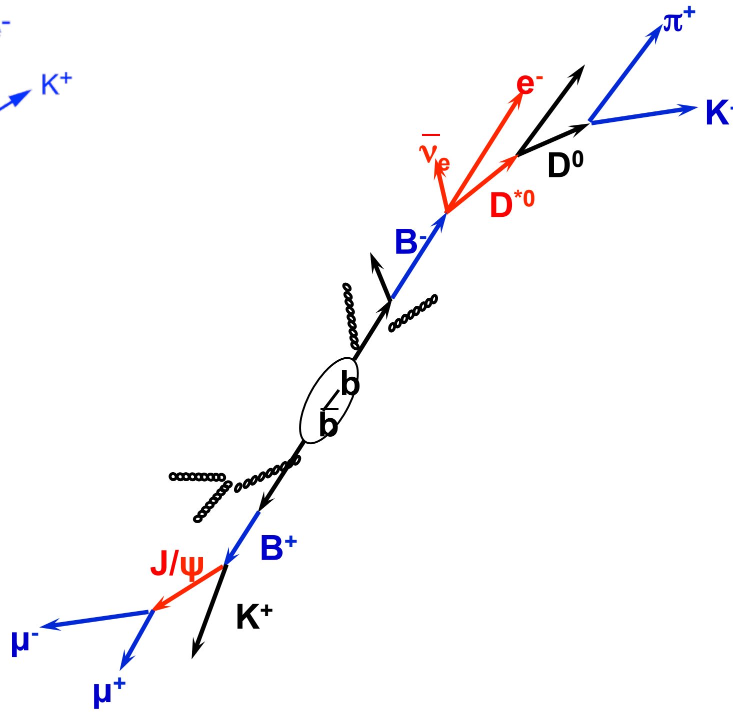
  STAR increase in FY14 replaces temporary loss and attempts to address succession planning and single point failure points

Runs 14-16: RHIC II is here

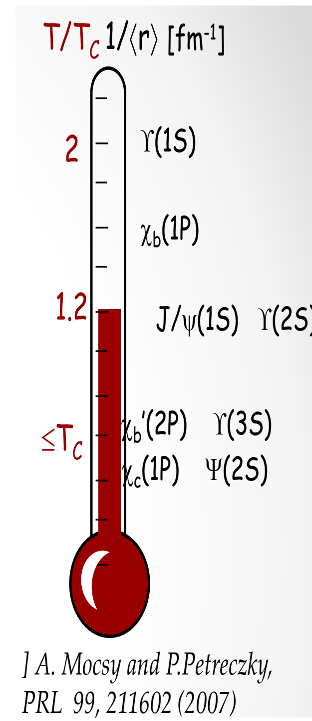
Charm



Beauty



Quarkonia



Stochastic cooling: more luminosity in this year than in all previous years combined

Detectors in place and fully operational to make full use of the luminosity

- Open Charm and Beauty: PHENIX VTX, FVTX; STAR HFT, MTD
- Quarkonia: PHENIX FVTX; STAR MTD
- Massive increase in DAQ rate to increase statistics for untriggered probes

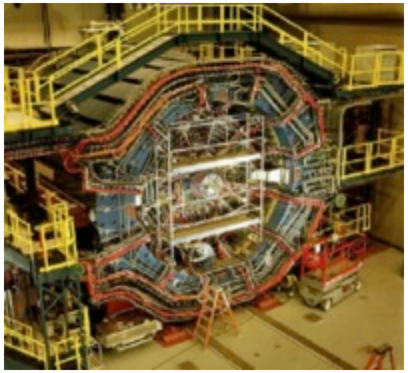
RHIC-II Detector Upgrades:STAR

★ MIE CE Cap. Equip. Ch China funds
In Indian contribution
Fr French contribution Ru Russian contribution

	Upgrade	Built	Operational
★ Ch	Time of Flight (TOF) $4.8M	FY 06-09	Run 10
CE	DAQ 1000 $1.8M	FY 06-08	Run 9
Ru CE	Forward Meson Spectr. (FMS) $0.8M	FY 06-08	Run 8
CE	Forward Gem Tracker (FGT) $2M	FY 08-12	Run 13
Ch In CE	Muon Telescope Det. (MTD) $1.8M	FY 12-14	Run 14
Fr ★	Heavy Flavor Tracker (HFT) $14.6 M (orig. 16.4)	FY 11-14	Run 14

Complete; Operating for physics

These upgrades have brought STAR from a low-rate tracking detector as originally designed to a high-rate detector with large-solid-angle capability for strange, charm and bottom particle detection, as well as forward-angle detection of hadrons and $W^{\pm}$ decays, at full RHIC-II luminosity.



RHIC-II Detector Upgrades:PHENIX

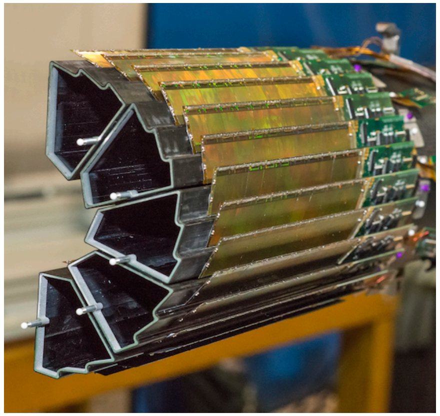
★ **MIE**
★ **NSF-MRI**
CE **Cap. Equip.**
Ja **Japan funds**
Fr **French contribution**
Sk **South Korean**

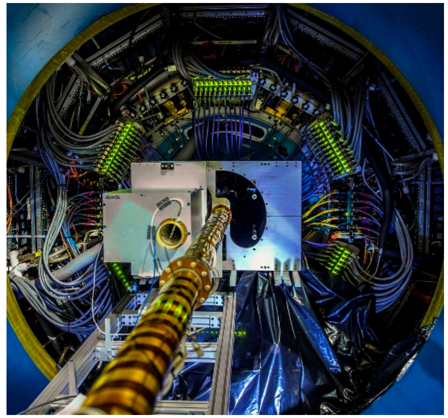
Funding	Detector	Status	Built	Operational
CE	Hadron Blind Detector $1.2M	Physics run complete	FY 05-09	Run 10
Fr ★ Ja	Si Vertex Tracker (VTX) $4.7M	Complete; Operating for physics	FY 07-11	Run 11
★	Forward Vertex Tracker (FVTX) $4.9M	Complete; Operating for physics	FY 08-12	Run 12
★ Ja	Muon Trigger $4.3M	Complete; Operating for physics	FY 07-11	Run 12
Sk	MPC-EX $0.9M	Under construction	FY 12-14	Run 15

These upgrades give PHENIX :

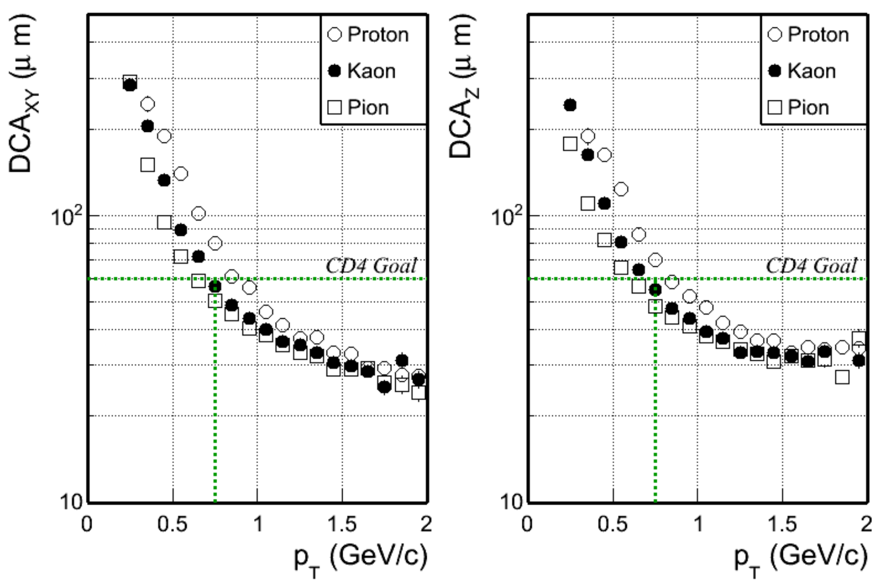
- **A unique look at background-suppressed low-mass e-pairs.**
- **The capability to exploit RHIC-II luminosities with the measurement of identified heavy flavor production in HI collisions, flavor-identified sea-quark contribution to the proton spin via W$^{\pm}$ decay in 500 GeV p-p collisions, and identified forward photons in p-p and d/p-Au collisions.**

STAR **Heavy Flavor Tracker**





$\sqrt{s_{NN}}$ = 200GeV Au+Au Collisions



Heavy Flavor Tracker (HFT)

Physics goal: **Precision measurement of heavy quark hadron production in heavy ion collisions**

All 3 sub-detectors (PXL, IST, SSD) were completed, installed prior to Run14

PXL – heart of the HFT: state-of-art detector, MAPS technology, first time used at a collider experiment. **Integration time ~ 187μs**

Reached all Key Performance Parameters: With survey and preliminary alignment, **Kaons at 750 MeV/c: DCA < 60μm**

Finished below budget and ahead of schedule

ESAAB for CD-4 Sep 25, 2014

Runs 15 and 16: refreshed PXL, with Al cables to maximize resolution

STAR HFT PXL Refurbishment

Run 14 not completely optimal

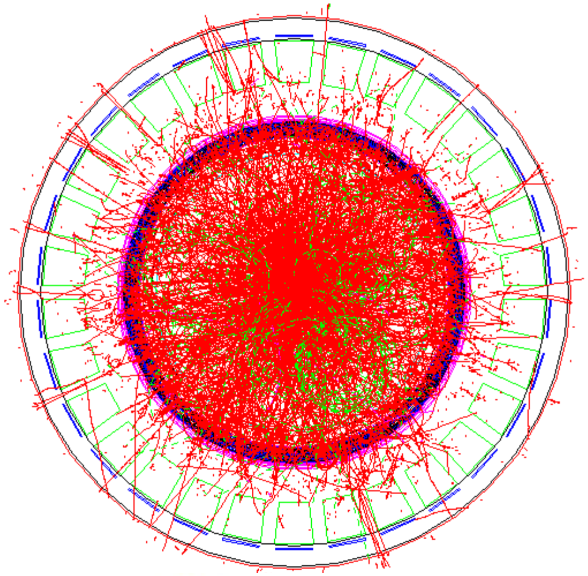
- Schedule and technical delays at the CERN shops led to non-optimal use of Cu rather than Al cables in the PXL for Run 14
- Under initial operation, digital damage occurred due to insufficient protection against latchup, leading to 16% loss in acceptance
- Combined led to more than a factor of 2 loss in statistical power

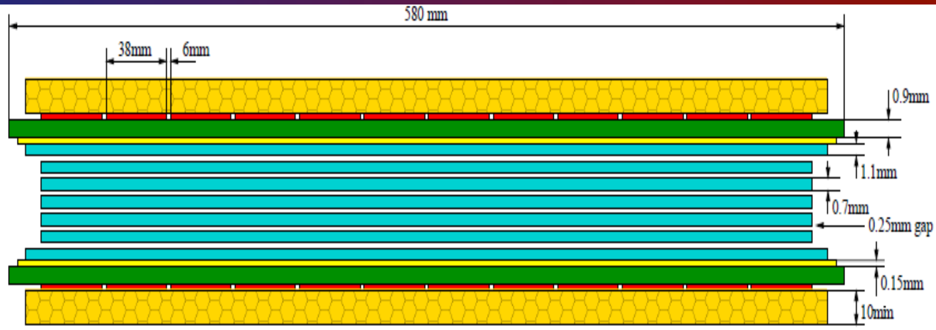
PXL detector built for rapid removal and refurbishment

- 2 complete sets of PXL detectors as project deliverable
- Second set completed and at BNL, with Al cables in inner layer
- Initial set refurbished as spare detector, also with Al cables
- Operational changes, especially tighter latchup control, solved the initial mortality issue for the remainder of Run 14, and will be effective in mitigating damage

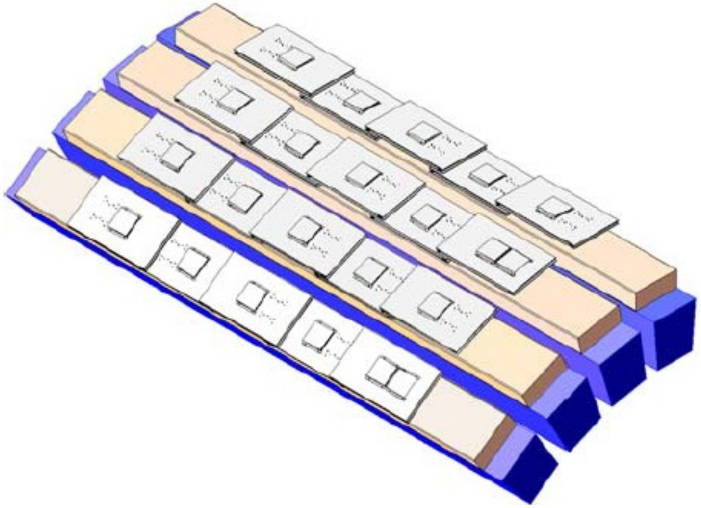
PXL will be fully functional with optimal performance for Runs 15 and 16

STAR Muon Telescope Detector (MTD)





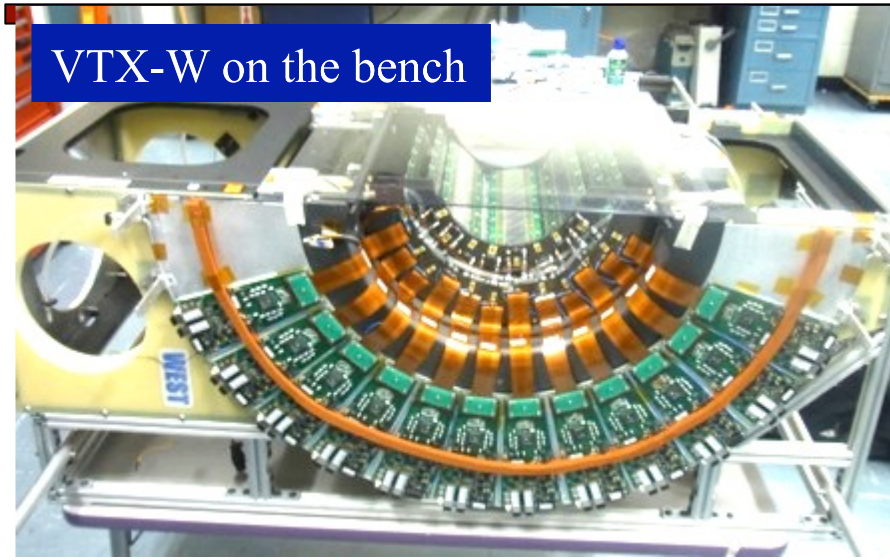
- **1.8M Capital Equipment project FY11-FY14**
  - **in collaboration with China and India**
- **Muon Tagger:** use the magnet steel as
  - absorber, TPC for tracking
    - Acceptance: 45% for $|\eta|<0.5$
- **Unique capability to identify muons at mid-**
  - **rapidity at RHIC**



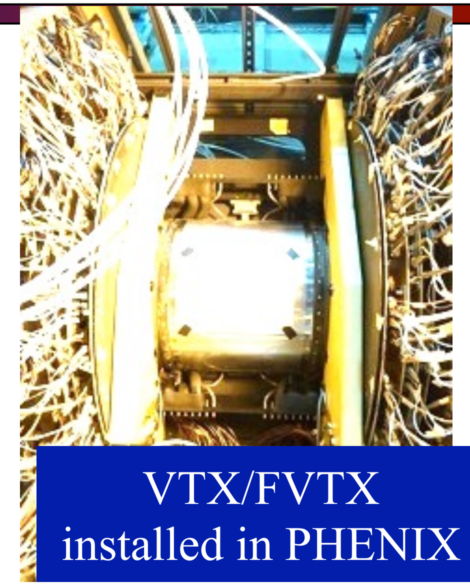
- **Installed and Completed for Run 14**
  - **Reached design performance, integrated ~half of multi-year proposed Au+Au luminosity as planned**

Institutions: BNL,UC Berkeley/SSL,UC Davis,Texas A&M,UT Austin;
China: USTC,Tsinghua; India: VECC

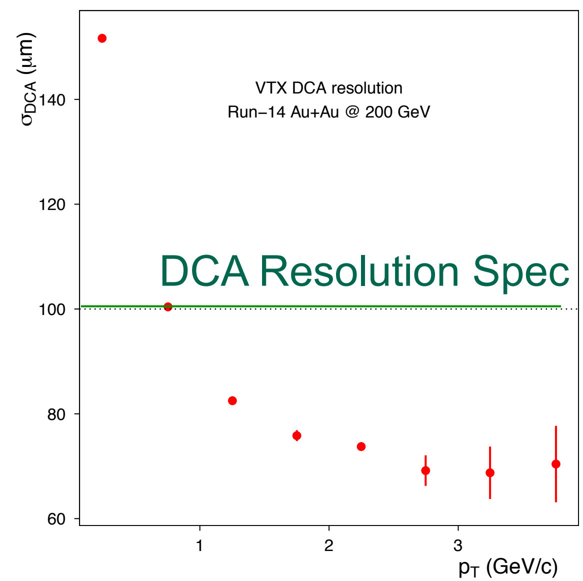
PHENIX VTX Refurbishment



Major refurbishment of PHENIX VTX prior to Run 14



Stripixel (40 ladders total) staves rebuilt for cooling
Pixel (30 ladders total) re-worked and re-installed



After refurbishment VTX/FVTX fully ready for flagship Run-14

Performance requirements exceeded

Greatly exceeded integrated luminosity goal

Lessons Learned

Especially from the HFT, but also applicable to other projects

- Successes:
- Develop early detailed design and tests
  - Significant cost and schedule savings and risk reduction when design fully developed early and there are few design changes
- Review other projects' lessons learned
  - Significant reduction in project risk, esp. in the IST cooling system which learned by discussions with PHENIX about closely related cooling system
- Project overview of budget allocation
  - Timely (monthly in the case of HFT) review with collaborating institutions to recognize cost overruns or savings early

- Improvements:
- Better interaction with BNL and Collaborating Institutions' Procurement Offices
  - Early planning, prompt followup

A Further Lesson Learned: Engineering Runs

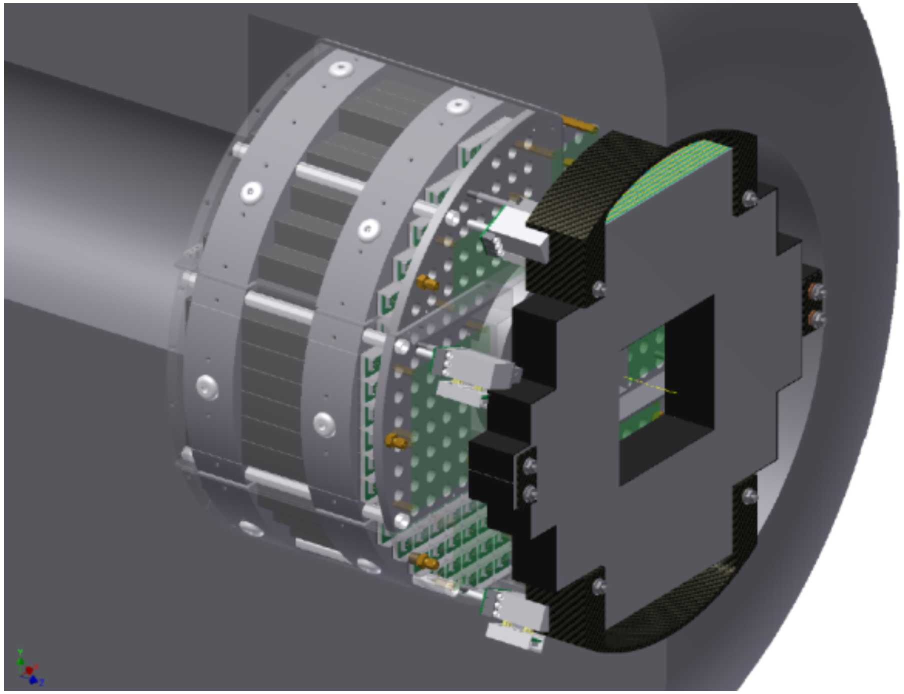
- Extremely helpful to have engineering runs
  - Successful projects implemented in stages
    - STAR DAQ1000: installed in one sector, followed next year by full installation
    - STAR FMS: years of prototype detectors
    - STAR TOF and MTD: multiple years of installation
    - PHENIX FVTX: installed second year of PHENIX vertex suite
    - STAR HFT: engineering run in Run 13 with a few PXL ladders
  - Many issues can be found and fixed with partial installation
    - Opportunity for design changes before full construction
    - Not necessarily without physics results: FMS and TOF prototypes had many physics publications starting from their first prototype runs in 2002 and 2003
  - Because of this, sPHENIX project is planning for partial installation for tail end of the Beam Energy Scan Phase 2

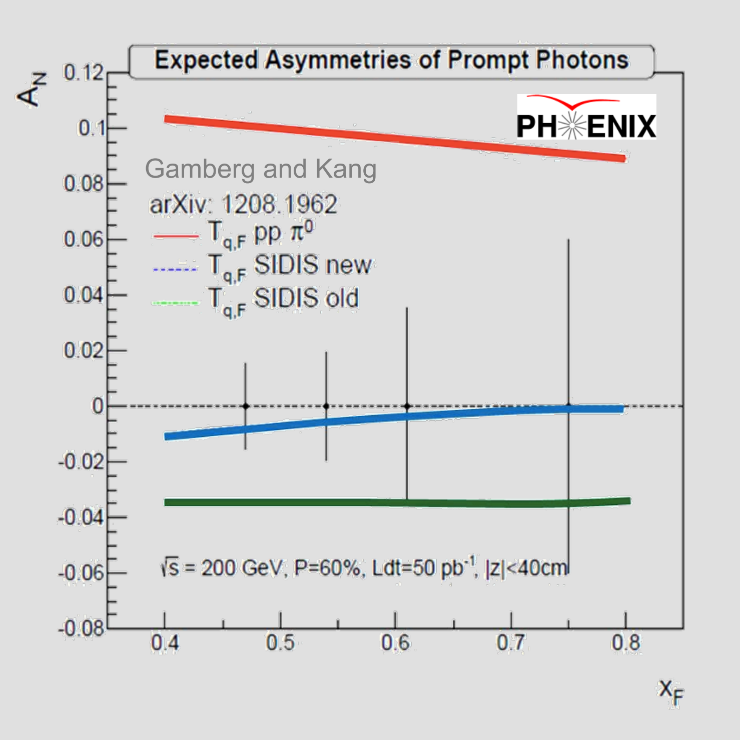
Run 15: further upgrades

- First ever polarized p+A collisions, further polarized p+p
- Serves both as baseline for heavy ion collisions and as a program in its own right
  - What is the gluon density in heavy nuclei at RHIC, and what role does saturation play?
  - What is the origin of transverse spin phenomena in p+p collisions at RHIC energies?
  - What in detail is the gluon contribution to the spin of the proton?
- Upgrades to both STAR and PHENIX in order to maximize capability in the forward direction
  - PHENIX: MPC-EX, preshowers for the forward EM calorimeters
  - STAR:
    - FMS refurbishment after damage during Run 13 p+p 500 GeV run
    - FMS Preshower, a preshower for the forward EM calorimeter FMS
    - Roman Pots Phase II*, reworking of placement of existing Roman Pots to allow for better reach in t and concurrent operation

PHENIX MPC-EX

Muon Piston Calorimeter (MPC) MPC-EX

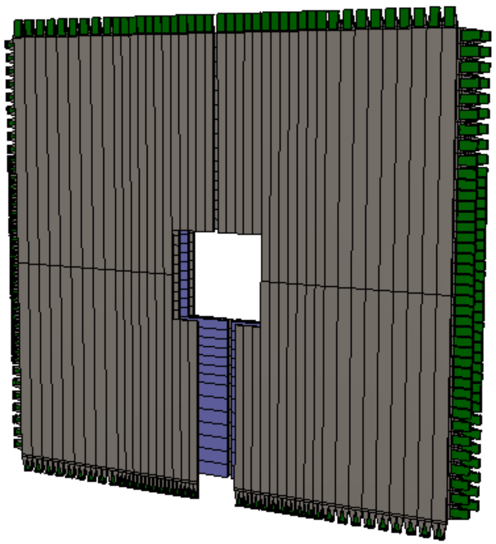




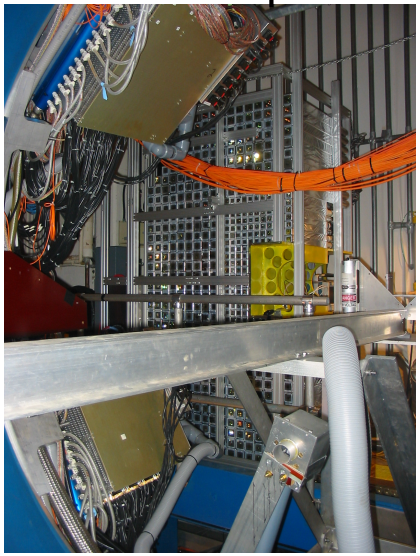
- Preshower for identification of forward prompt photons
  - Clean probe of transverse spin asymmetries in both p+p and p+A
- Capital equipment project tracked by BNL and DOE
  - $0.9M US funds, strong collaboration with South Korea
- On schedule for full installation in Run 15

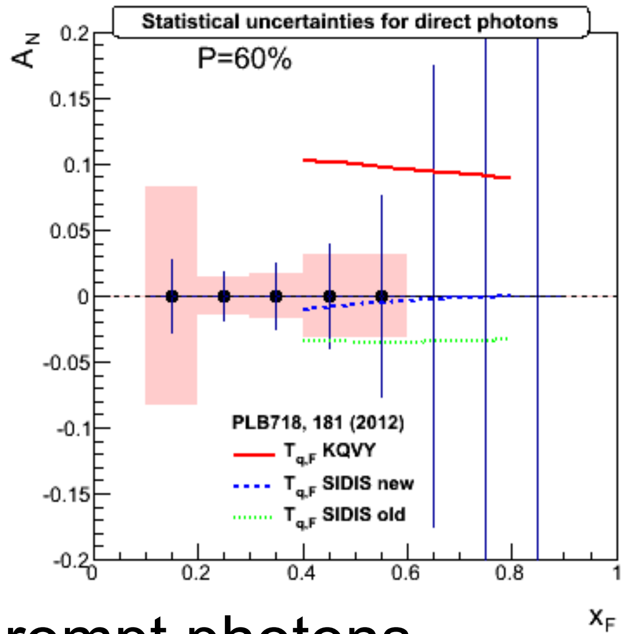
STAR FMS refurbishment and FMS Pre-Shower

FMS Preshower



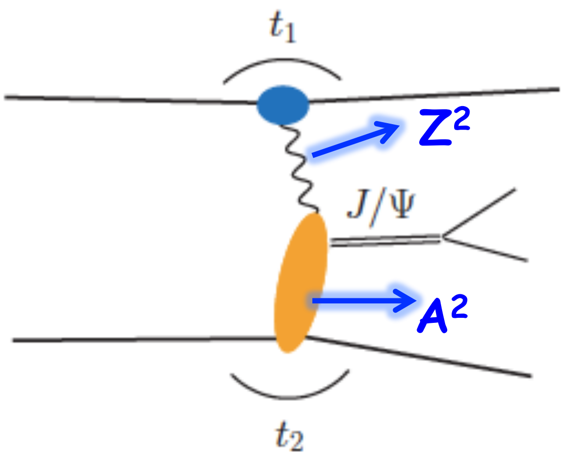
Forward Meson Spectrometer





- Preshower for identification of forward prompt photons
  - Similar performance as PHENIX MPC-EX
  - Important to have two such challengingf measurements
- Minor upgrade and refurbishment of existing detector
  - Anneal Pb-Glass array on loan from Russia, new phototubes from decommissioning of D0
  - Preshower R&D: first moderate-scale implementation of Silicon Photomultipliers in RHIC environment

STAR Roman Pots Phase II*

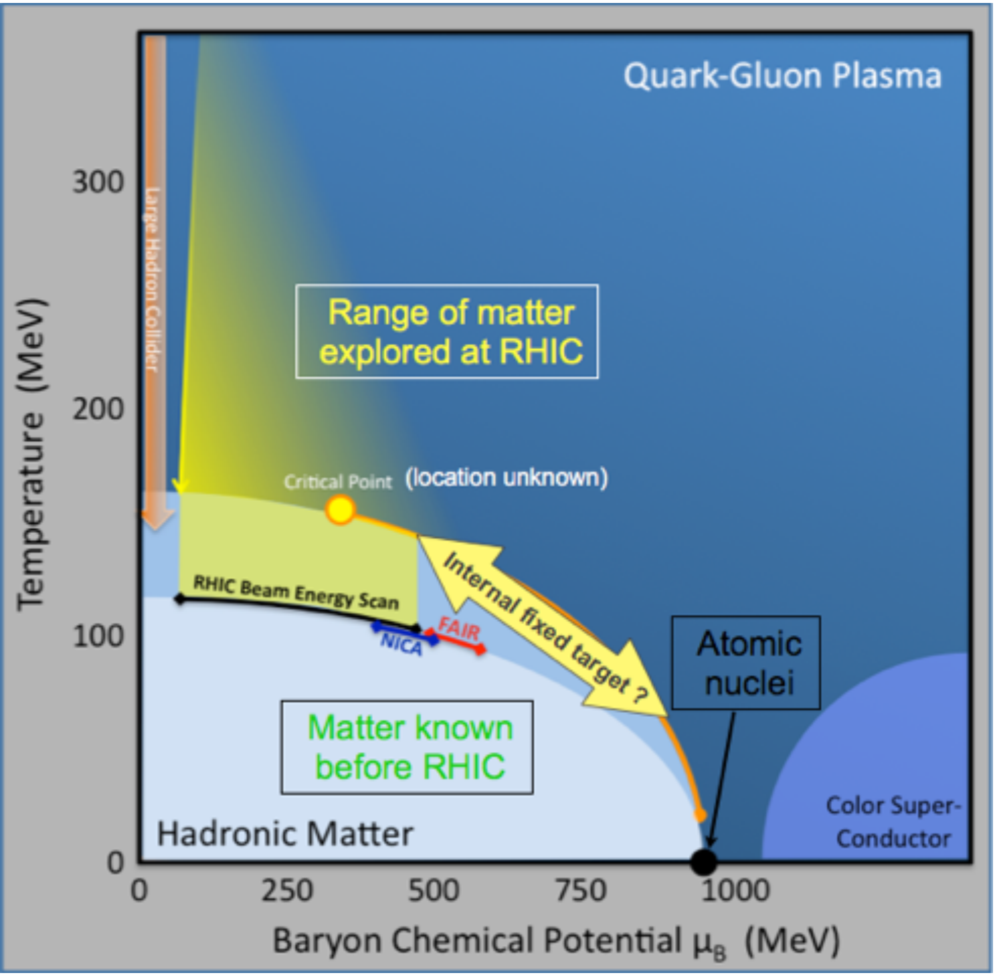


From Ultra-Peripheral p↑+A collisions:
First look at Generalized Parton Distribution E_g for gluons before the EIC

$$A_{UT}(\tau, t) \sim \frac{\sqrt{t_0 - t}}{m_p} \frac{\text{Im}(E * H)}{|H|} \qquad t = \frac{M^2_{J/\Psi}}{s}$$

- Minor upgrade of existing detector component to change position, along with modification to shielding necessary for any p+A operation
- Increases physics reach, allows for concurrent operation, rather than special optics requiring dedicated beam time
- On track for completion for Run 15

Beyond Run 16:Mapping the QCD Phase Diagram



RHIC uniquely suited to map the QCD phase diagram at finite baryon density

- Controlled introduction of baryon density: from well-understood crossover to possible new behavior

Hints of new behavior in first Beam Energy Scan

Beam Energy Scan Phase 2:

Move from hints to quantitative understanding

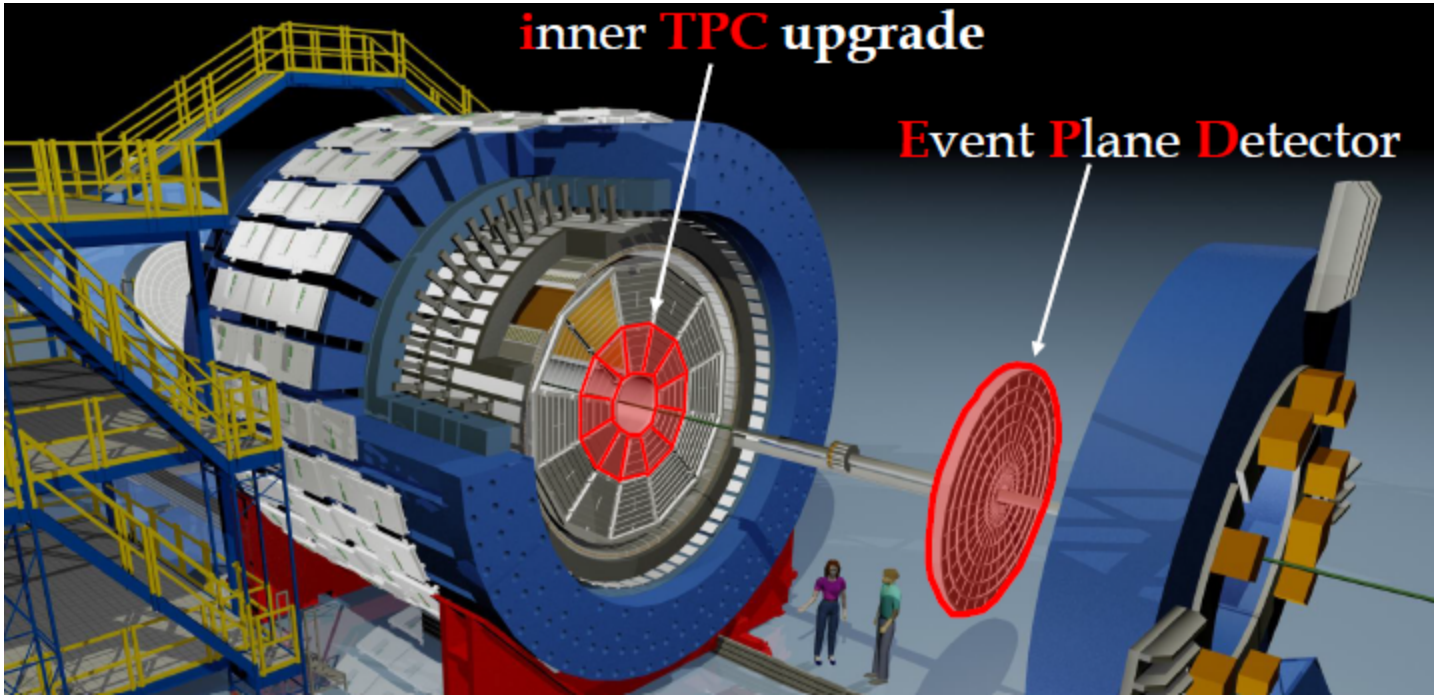
Comments from the Program Advisory Committee

- "BES data, at present and in future from BES-II, together with the concerted theoretical response that present data motivates, will yield quantitative understanding of the properties of strongly coupled matter in the crossover region where QGP turns into hadrons, with quantitative connection between measured quantities and QCD. This, in and of itself, is an outstanding scientific goal."

- "If Nature puts a critical point in the region of the phase diagram with μ_B < 400 MeV, with a first order phase transition starting at the critical point, BES-II data on fluctuation and flow observables at $\sqrt{s_{NN}}$=19.6 GeV and below together with the theoretical tools developed in response to BES-I data should yield evidence for both the critical point and the first order phase transition. This cannot be counted on, but if achieved it would constitute a landmark for the field as well as on the phase diagram."

- "We strongly support BNL and its C-AD in their plan to provide the electron cooling needed for the BES-II program, to run in 2018 and 2019."

Upgrades for STAR for BES Phase 2



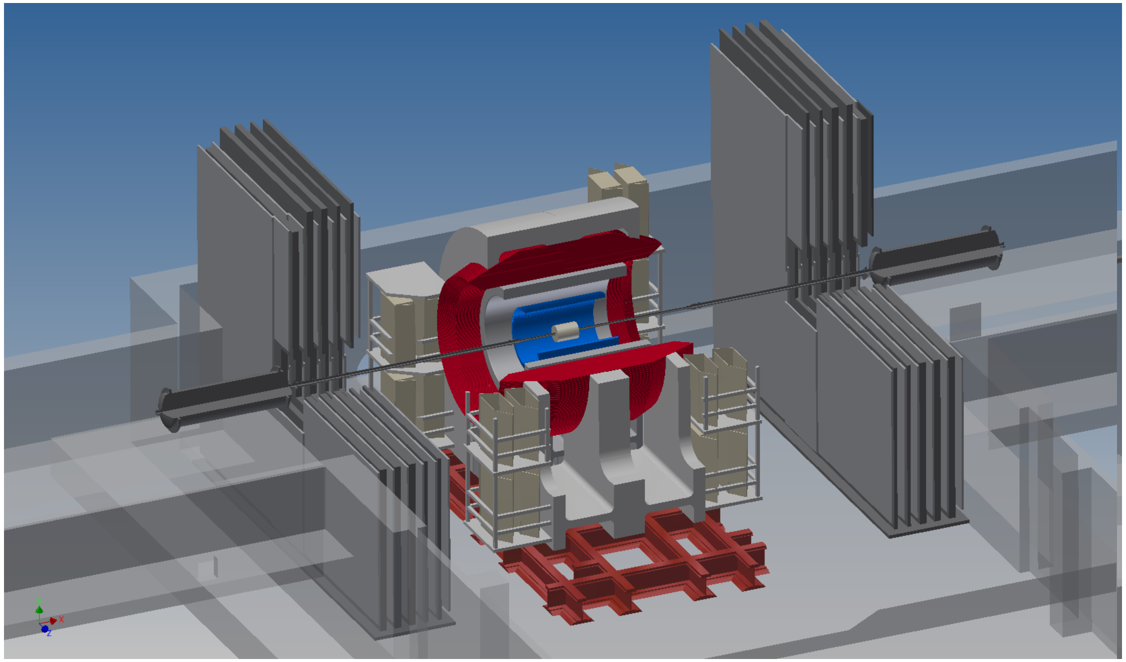
Maximize physics reach with moderate upgrades

Inner TPC Upgrade: expand particle identification and rapidity coverage
- US contribution at Capital Equipment scale (<$2M)
- Leveraging: construction of chambers by China
  - ALICE/Brazil technical partner in electronics development

Event Plane Detector: minor upgrade to enhance triggering, flow measurements

Expect detailed proposals for review in FY15

Beyond Beam Energy Scan: return to high luminosity A+A

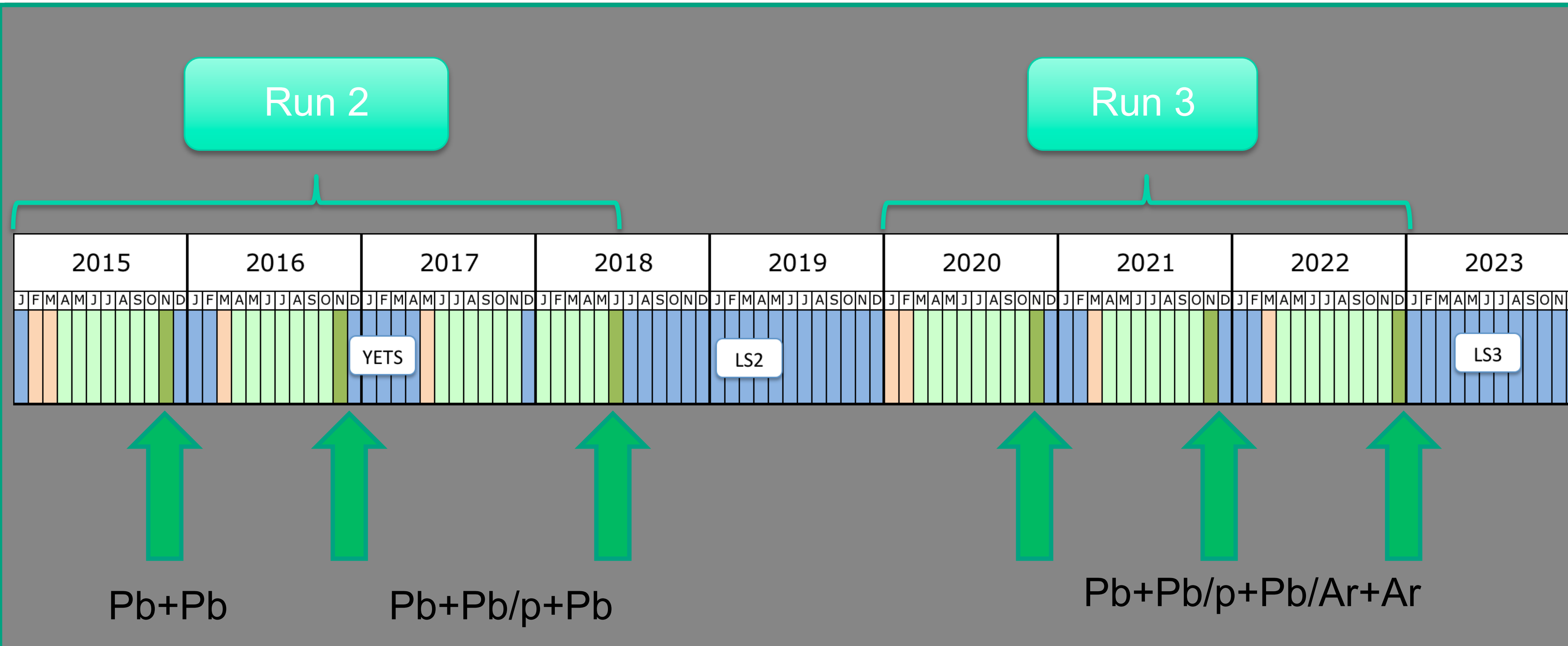


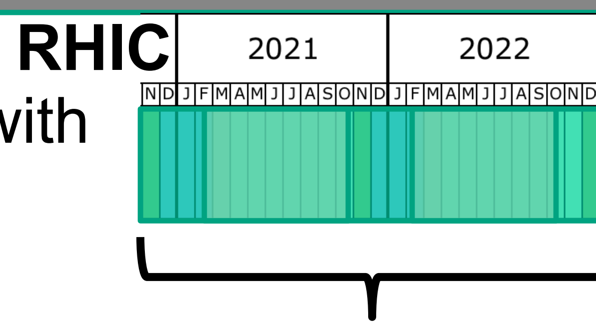
sPHENIX:
Large-scale MIE to replace PHENIX with a detector optimized for jets and quarkonia
Reuses existing infrastructure of PHENIX and BABAR solenoid

Local oversight at BNL: ALD office, with input from sPHENIX Project Management Group, consisting of experts outside the project from HEP and NP

DOE-charged science Review in July 2014

RHIC in Context in 2021-2022

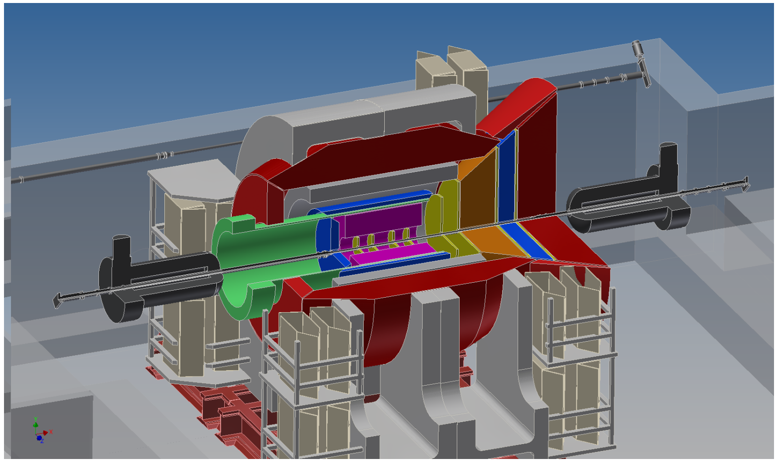


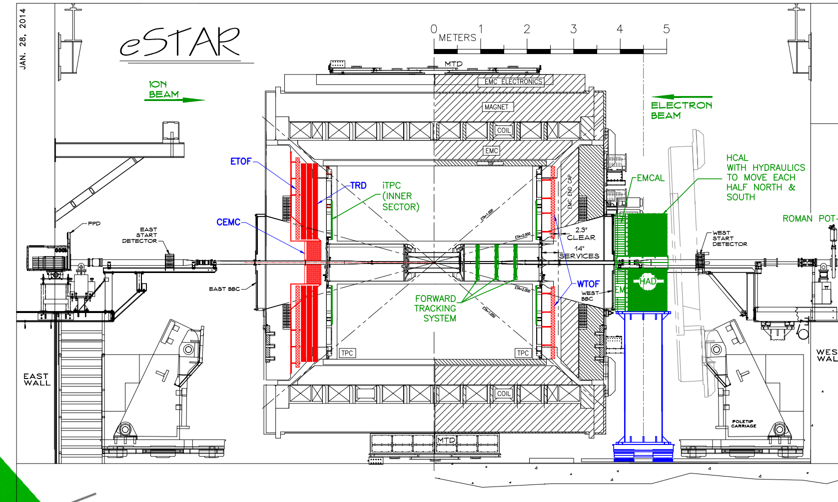


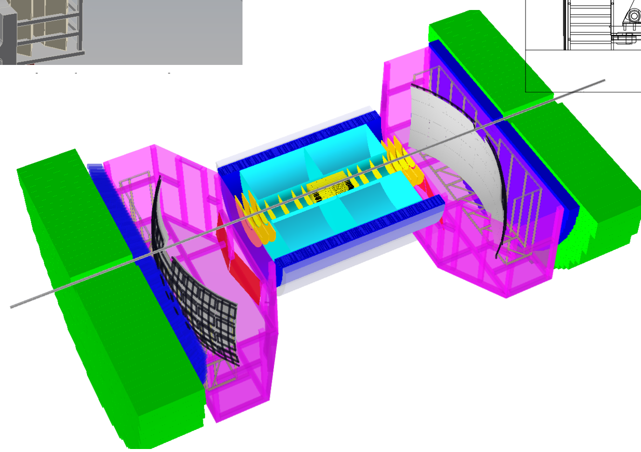
sPHENIX measurements well timed with LHC Run-3 measurements

Enabling theory focus on simultaneous understanding

Beyond RHIC: EIC and eRHIC realization





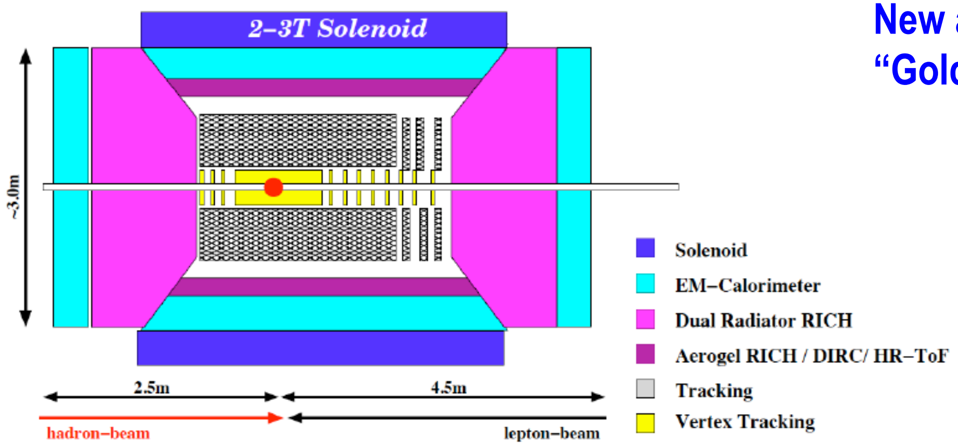


- eRHIC design study available at http://arxiv.org/abs/1409.1633
- Three detector designs currently explored
  - Partial reuse of STAR and sPHENIX, along with a model detector
- When closer to realization, call for proposals and collaborations

Electron Ion Collider Generic Detector R&D

Peer-Reviewed program established in 2011 to enable EIC experiments

Funded by DOE; managed by BNL: ~1M$-1.5M$/year

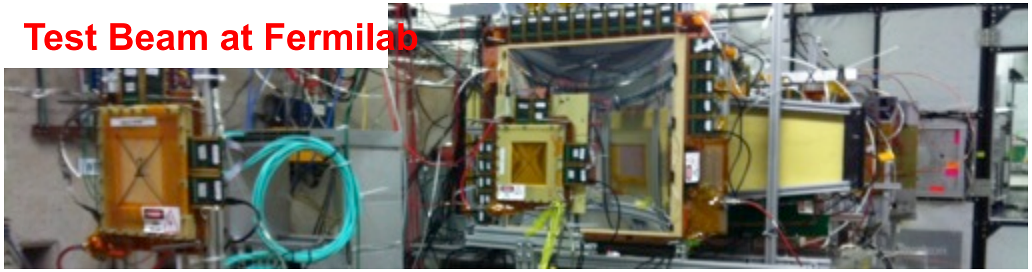


New and improved detector technology, focused on EIC "Golden Measurements" in the collider environment.

Essential software development for EIC physics simulation and experiment design.

Coordinated efforts among CEBAF, RHIC, and HEP communities.

Test Beam at Fermilab



Initiating consortia of Universities and National Labs as a first step toward building scientific collaborations to successfully mount EIC experiments.

Standing Advisory Committee meets twice per year. Recent meeting: July 21-22, 2014

EIC Detector R&D: Funded Projects through FY14

Prop. No.	Title	Contact	Institutions
RD 2012-5	Physics simulations	T. Ullrich	BNL
RD 2011-1; RD 2012-14	Tungsten fiber calorimeters	H. Huang/ C. Woody	UCLA, TAMU, Penn St., BNL, USTC
RD 2012-13	Forward EM pre-shower	W. Brooks	UTFSM (Valparaiso, Chile)
RD 2011-5	Radiation resistant Si PM	C. Zorn	JLab
RD 2011-6; RD 2012-9; RD 2012-16	Tracking/PID/Simulation	K. Dehmelt/ T. Hemmick	BNL, BNL/RBRC, Florida Inst. of Technology, Iowar State, LBNL, MIT, Stony Brook Univ., Temple Univ., Univ. Virginia, Yale Univ., JLab
RD 2012-3	Tracking: GEM & Micromegas	B. Surrow, F. Sabatie	CEA Saclay, MIT, Temple Univ.
RD 2011-3; RD 2012-7	DIRC -based PID	P. Nadel-Turonski	Catholic Univ. of America, Old Dominion Univ., Univ. of South Carolina, JLab, GSI Darmstadt
RD 2012-12	Forward RICH detector	V. Kubarovsky	JLab, INFN Frascati, INFN Ferrara, Christopher Newport Coll., UTFSM (Valparaiso, Chile)
RD 2012-15	Gem based TRD	Z. Xu, M. Shao	ANL, BNL, Indiana Univ., USTC (China), VECC (India)
RD 2012-11	Spin-light polarimeter	D. Dutta	Mississippi State Univ., Coll. Of William & Mary, Stony Brook Univ., Gutenberg Univ. (Mainz), UV Charlottesville, ANL, JLab
RD 2013-2	Magnetic field cloaking device	A. Deshpande	Stony Brook Univ., RIKEN, BNL

Simulation tools

Compact, Fine Grain Calorimetry and Photon Detection

Simulations; Micropattern Tracking; Particle ID; Hermiticity

Forward e-Tagging

e-Beam Polarimetry

Detector/Beam Interface

EIC Detector R&D: Funded Projects for FY15

R&D ID	Title	Contact	Institutions
eRD11	RICH detector for the EIC'S forward region particle identification	Yi Qiang	Argonne National Lab, Brookhaven National Lab, Georgia State University, INFN - Sezione di Ferrara, Jefferson Lab, Los Alamos National Lab, Old Dominion University, University of New Mexico, Universidad Tecnica Federico Santa Maria
eRD10	R&D Proposal for (Sub) 10 Picosecond Timing Detectors at the EIC	Mickey Chiu	Argonne National Laboratory, Brookhaven National Laboratory, Howard University, University of Illinois at Urbana-Champaign, University of Massachusetts at Amherst, Yale University
eRD4	DIRCbased PID for the EIC Central Detector	Pavel Nadel-Turonski	University of South Carolina, GSI, The Catholic University of America, Old Dominion University, Thomas Jefferson National Accelerator Facility
eRD3	Design and assembly of fast and lightweight barrel and forward tracking prototype systems for an EIC	Bernd Surrow	CEA Saclay, Temple University, College of Science and Technology
eRD2	A Compact Magnetic Field Cloaking Device	Abhay Deshpande	RIKEN BNL Research Center, Stony Brook University, RIKEN, Brookhaven National Laboratory, Seoul National University
eRD1	EIC Calorimeter Development	Huan Huang/Craig Woody	Brookhaven National Laboratory, California Institute of Technology, The Catholic University of America, Thomas Jefferson National Accelerator Facility, Indiana University, IPN Orsay, Pennsylvania State University, Texas A&M University, University of California at Los Angeles, University of Science and Technology of China, Yerevan Physics Institute
eRD6	RD6 Tracking/PID Consortium	Klaus Dehmelt	Brookhaven National Lab, Florida Tech, Lawrence Livermore National Lab, Stony Brook University, University of Virginia, Weizmann Institute of Science, Yale University
eRD12	Proposal for an electron polarimeter a luminosity monitor and a low Q2 tagger	Elke Aschenauer	Brookhaven National Laboratory, Byelorussian State University, Cracow University of Technology

Synergy: Calorimeter R&D Consortium (eRD1)

EMCal & HCal Team at BNL

Prototypes arriving at FNAL Meson Lab

HCal and EMCal prototypes on Fermilab Testbeam floor

Calorimeter R&D:
Tests of EMCal and Hcal technology for STAR, PHENIX, and EIC at Fermilab spring 2014

Results have led to downselect choice of sPHENIX EMCal technology to a variant of the EIC version

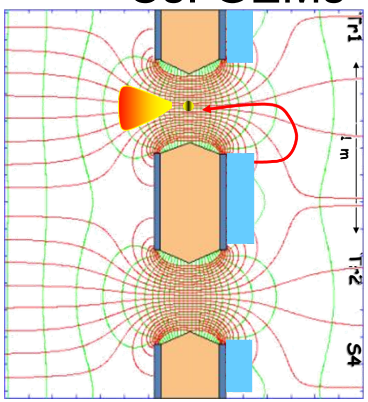
Major EIC Consortia: Tracking (eRD6/eRD3)

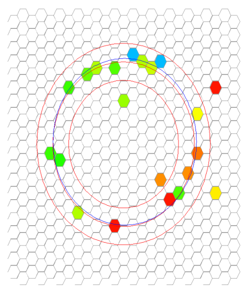
Advancing GEM technology

One Goal: produce large-area GEMs in the United States

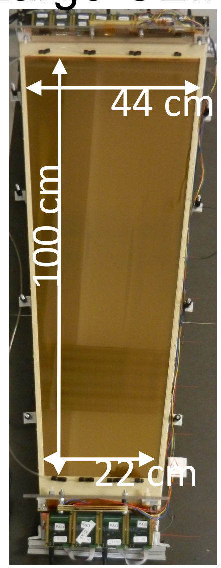
- Transfer technology from Europe to US industry and universities
- Advance technological use of GEMs to improve precision

CsI GEMs

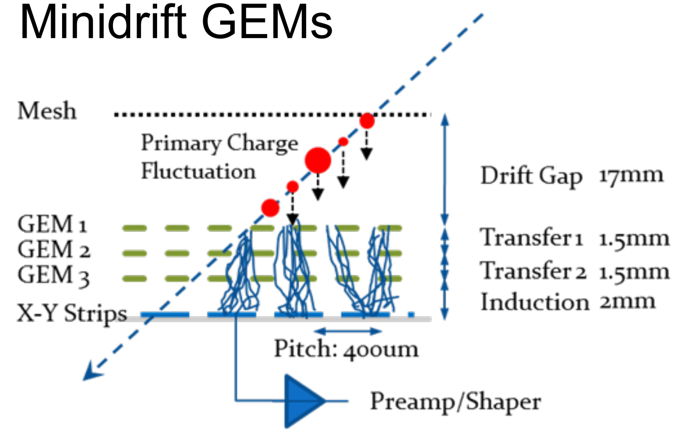




Large GEMs



Minidrift GEMs



eRD6: Brookhaven National Lab, Florida Tech, Lawrence Livermore National Lab, Stony Brook University, University of Virginia, Weizmann Institute of Science, Yale University

eRD3: CEA Saclay, Temple University

Summary

- Planning of physics and operations needs tightly coupled
  - RHIC II is here, with successful upgrade projects
    - World-class and innovative detectors doing world-class science
    - STAR HFT under budget and ahead of schedule
  - Experimental Operations successful, but tight
    - Currently able to keep up with additional complexity of detectors and computing needs with constant effort
    - Attempting to address single point failure points and succession planning under constrained budgets
  - Future plans developing well, with significant needs
    - Run 15: expect success in minor upgrades for first ever polarized proton-ion collisions
    - Planning for STAR upgrades for Beam Energy Scan II in earnest in FY15
    - sPHENIX project developing strongly in coming year
    - EIC Detector R&D program continuing to build community and technological support necessary for success